SOLVE-II Flight Report: Wednesday, 01/29/2003

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Flight Type: SAGE-III occultation & North Pole flight

Flight Objectives:

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2. SAGE III occultation: 71.94˚N, 23.09˚E at 10:19:41 UT
   - 3 sun runs
3. Overflight of Ny Ålesund
4. Profile into flow region across vortex core near pole
5. Profile air mass near Eastern Greenland

Flight Plan (UT):

08:02 Takeoff
10:13 Sun run #1 – Waypoint 6
10:20 SAGE III occultation – Waypoint 7
10:45 Sun run #2 – Waypoint 9
11:04 Sun run #3 – Waypoint 11
12:44 Ny Ålesund Overpass – Waypoint 14
14:17 North Pole – Waypoint 16
17:47 Landing

Forecast Meteorology:

Flight Meteorology:

Flight Report:

Everything was 'go' on the ramp, and it wasn't snowing for once. Took off at 8:01 UT. Kiruna was overcast on takeoff but we broke through the clouds at about 7 kft. As we flew to waypoint 4 over the Atlantic, we moved through some cirrus that decreased as we ascended. We were through the cirrus at about 27 kft. By the time we had leveled off at 35 kft, ozone was up to 285 ppbv, H_2O was down to 5.5 ppmv, CO had decreased to 34 ppbv, at a theta value of about 320 K. Winds were about 30 kts @ 278˚ and T was about –61˚C. MTP showed the tropopause at about 30 kft.

During the ascent, FastOz reported unusual behavior in the tropopause region with respect to the ozone profile. Ozone rapidly increased at the tropopause, but fell off again as we continued to ascend, and then increased again to the values we saw at 35 kft. This layer of low ozone had about 22 ppmv of water. We speculate that this unusual layer may be air that was pushed up into the polar lowest-most stratosphere by an upper-tropospheric anti-cyclonic system.

We made waypoint 4 approximately on time, with a zenith angle near 93˚. As we flew NNE, we were passing through the edge of the polar vortex. Ozone decreased dramatically from 2.5 – 2.8 ppmv down to about 1.8 ppmv. AROTAL-LaRC and DIAL both showed weak enhancements of aerosols near 14 km. AROTAL-LaRC also showed a very strong enhancement of aerosols between 30 and 32 km.

This track from the SW to NE (waypoints 4-5) was intended to characterize the air that was flowing over the Scandinavian region. SAGE III was doing a limb scattering test as it orbited northward. The ozone and aerosol profiles acquired by the lidars upstream of this limb scattering test would allow us to understand the limb scattering retrieval in a difficult part of the atmosphere: the edge of the polar vortex. Large vertical and horizontal variability in this area provides a stringent test of the ability of a satellite to accurately retrieve ozone and aerosols.

We climbed to 37 kft at about 10Z. Prior to the climb, H_2O=5.4 ppmv, CO=36, ozone=294, theta=317.5K, v=24 @ 301˚, T=-61.7˚C – clearly stratospheric air. After we leveled off, H_2O=4.1 ppmv, CO=30, ozone=367, theta=329K, v=23 @ 297˚, T=-60.6˚C – deeper into the stratosphere as indicated by the temperature and the constituents.

We started our 1st sun run at 10:17Z with a zenith angle of about 90.2˚. All 3 solar instruments reported that they locked onto the sun early in the start of the run. The SAGE III occultation was at 10:19:41, so we were about 5-6 minutes late for the start of this run. We passed the SAGE III tangent point at about 10:26. AROTAL reported that the aerosol layer at 31 km was still present, but weaker than near the upstream waypoint 4 to 5. They also reported a possible layer between 34-35 km. Completed the sun run at 10:32 at waypoint 8. GAMS/LAABS reported good data over most of the sun run with a slight increase in ozone over the run. There was a little problem with the filter at the start. DIAS reported that they tracked and took data through the run. AATS-14 reported good data with optical depths in the mid-visible of about 0.01. Above 16 km, AROTAL and DIAL saw an increase of ozone over the course of the run.

We started our 2nd sun run at approximately 10:52Z. Again, all three instruments locked onto the sun at the start of the run. We completed the run at 11:07 with a zenith angle of 89.5˚. GAMS/LAABS had a good run, with relatively slow variability. DIAS again took good data and saw photons down to 322 nm. AATS-14 again tracked the sun and retrieved optical depths.

Since the winds were directly down our sun run tracks, it was unlikely that we'd intercept our own plume except near the start of the 3rd sun run. In fact, during this sun run, DIAPER reported five separate intercepts of fresh plumes. At the same time, our pilots reported aircraft that were roughly paralleling our track, so there's some uncertainty about whether we intercepted our own plume. Each intercept was on the order of a few seconds in duration.

We started our 3rd sun run at 11:27Z. Again, all three solar instruments began tracking onto the sun at the start. Ended at 11:44Z with a zenith angle of 90.4˚.

Started north towards Ny Ålesund at 11:44Z from waypoint 12 at 72˚N. All 3 instruments worked well. GAMS/LAABS reported rather stable spectra throughout the run. AATS-14 did a field-of-view scan at the end of the run, and found that their window was not contaminated by ice.

From the aircraft viewpoint, the comparison with the SAGE III limb view mode and the occultation was very successful. The region was fairly well characterized by ozone and aerosol retrievals. There was some substantial variability of ozone in this region because of both ozone loss, and dynamical effects near the edge of the polar vortex. AROTAL in particular noted some very low values of ozone near 20 km at the western end of the 3rd sun run. This data set will provide an excellent challenge for the limb retrieval.

Figure 1. Low-level clouds and broken sea ice observed from the NASA DC-8 on January 29, 2003 at a latitude of 74˚N between the Norwegian coastline and Spitzbergen Island.

The in situ ozone increased as we progressed northward. Near Ny Ålesund, H_2O was 3.9 ppmv, CO=32.6, ozone=368, T=-61.8, theta=326.8, and v=18 kts @ 328˚.

Once again we passed over Ny Ålesund. We were precisely here at 12:44Z, as planned. We had another great view through the DC-8's down-looking camera of frozen Ny Ålesund. As we moved north ozone began to decrease at 20km, at 80˚N ozone decreased to 1.3 ppm according to the AROTAL instrument. In situ ozone slowly decreased to 332 ppm and CO rose to 150 ppm, theta=326. The aerosol layer at 14.5 km began to thicken and a second layer began to form at 18 km. Ozone began to decrease at 15 km and below. North of 82˚N the FastOZ ozone and CO measurements showed a lot of structure – possibly a gravity wave off of Ny Ålesund. DIAL thinks that the aerosol layer at 18 km is associated with an ozone minimum. A filament of ozone was observed by the lidars at 18 km – 13:05-13:10Z. Ozone began to increase in the lower stratosphere as we approached the other side of the vortex. Lost GPS as we approached the pole.

By 86˚N, we were clearly passing out of the vortex at upper levels. Ozone isopleths were showing fairly strong descent. AROTAL was showing fairly strong vertical waves in the temperature profiles with amplitudes of over 5-6K and a 6 km vertical wavelength at altitudes above 30 km. DIAL showed thick and extensive clouds below us at this time. These clouds extended up to about 8 km.

We overflew the pole at 14:13Z. We were very clear that we were passing out of the vortex at upper altitudes. Both the aerosol layer and the ozone profiles show clear signatures of the extra-vortex air. Near the pole the H_2O=4.5, CO=153, ozone=331, T=-63, theta=324.5, winds were messed up. After hitting the pole, we ascended from 37 to 40 kft. After ascent: H_2O = 3.5 ppmv, CO=28, ozone=466, T=-62˚C, theta = 340, and winds were messed up a bit.

Figure 2. DC-8 Navigator Kevin Hall points to his GPS display. The display shows the latitude and longitude of the plane. At this time, we had just passed the pole, and we were at 89˚42.7'N.

On our southbound leg from the pole, the lidars showed a mirror image of the observations taken as we approached the pole. The filament observed on the northbound leg re-appeared at a slightly higher altitude on this southbound leg.

As we re-crossed the region north of Spitzbergen, ozone began to again show some rather extreme swings.

With the exception of this PV filament high of ozone (see Figure 3), ozone was generally between 1.3-1.8 ppmv at 20 km inside the vortex. As we neared waypoint 18, we turned SE for return to Kiruna. At this point, we had predicted a local PV high at 330 K (near our flight altitude). Shortly before arrival at waypoint 18, ozone went to over 550 ppbv at a potential temperature of approximately 340K. We may the turn at waypoint 18 at 16:08 Z. Observed winds and temperatures were very close to predicted values at this location.

On the inbound leg into Kiruna we slowly exited the vortex. This was apparent in both the DIAL and AROTAL ozone and temperature data. We started our descent at 17:17Z and landed at 17:47Z.

Pilots: Dick Ewers, Ed Lewis
Navigator: Kevin Hall
Mission managers: Chris Miller & Tom Mace
Mission scientist on board: Paul A. Newman & Mark R. Schoeberl

Status Report: Instrument – PI

DIAPER (in situ aerosols) – Anderson
Had a good flight. Everything worked. Intercepted multiple A/C plumes. Saw cirrus and other interesting things.

SP2
Had a good flight.

FastOz – Avery
Instrument had a good flight. Interesting profile on ascent.

DACOM/DLH (in situ trace gases and open path water vapor) – Diskin
It was a lot of fun. Some noise early on CH4, but worked OK. DLH worked well.

PANTHER (in situ PAN and other trace gases) – Elkins
Had good chromatography throughout the flight. Had to relaunch software 3-4 times for a loss of 15 minutes of data or so.

MTP (microwave temperature profiler) – Mahoney
Had a good flight. Retrievals were in good agreement with radiosondes. Profiles a bit too cold on high end.

AATS-14 (sun photometer) – Russell
Had a good flight.

GAMS/LAABS (solar occultation ozone, aerosols and oxygen A band) – Pitts
Had a little glitch with a filter at the beginning. However, a very good flight overall. Some differences in ozone from run to run.

DIAL (Lidar ozone and aerosol above and below the AC) – Browell
Had a good flight. Interesting fold near 80˚N.

AROTAL (Lidar ozone, aerosols and temperature above the AC) - McGee/Hostetler
GSFC – Had a great flight. Instrument worked extremely well. Saw ozone loss. Saw the symmetry about the polar region up to altitudes of about 38km.
LaRC – Had a good flight. Saw some structure in aerosols on the vortex edge. Had to reboot the computer a few times. Saw 40% higher aerosols coming back compared to going out.

DIAS (Direct beam solar irradiance) – Shetter
Got data through all tjree sun runs. Got data down through 320 nm.

FCAS/NMASS (in situ aerosols) – Reeves
Automated.

Differential GPS – Muellerschoen
Worked well. Some drop outs.

ICATS
Had a good flight. No computer crashes. From 14:12 to 15:20Z, longitudes will be incorrect.

Plots (flight plan, solar zenith angles, Rel. humidity):

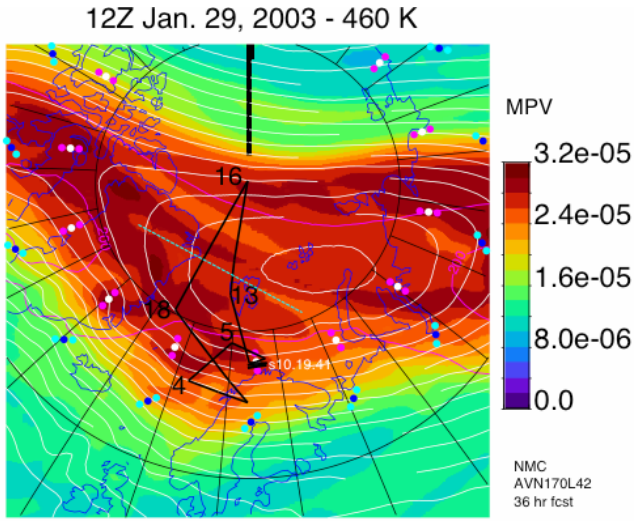

Figure 3. January 29, 2003 DC-8 flight plan (black) superimposed on a 12Z map of modified potential vorticity (color image) for the 460K isentropic surface. The thick magenta line on the left shows the 200- and 205-K temperature contours. The white point indicates the SAGE III occultation point and the dark blue points are POAM occultation points. The white lines are Montgomery stream function lines (winds blow parallel of these line). The dashed green line extending between Spitzbergen and Northern Greenland indicates the axis of a PV low. A maximum of ozone was observed on both the northbound leg and southbound legs of this flight at approximately the position of this dashed green line.

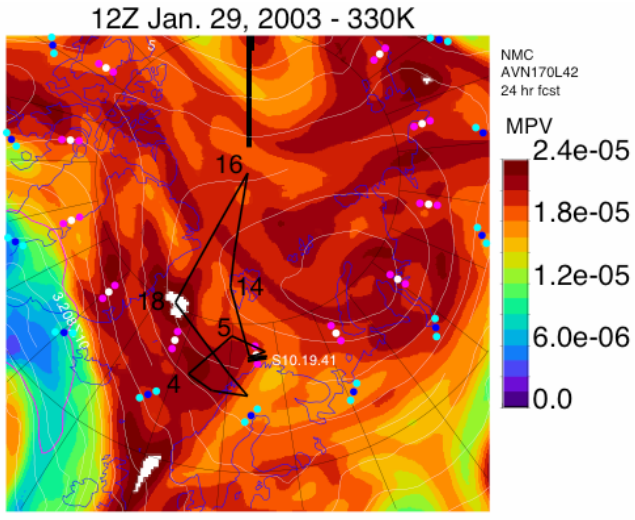

Figure 4. As in the previous figure, but for the 330-K isentropic surface (approximately the DC-8 flight altitude)

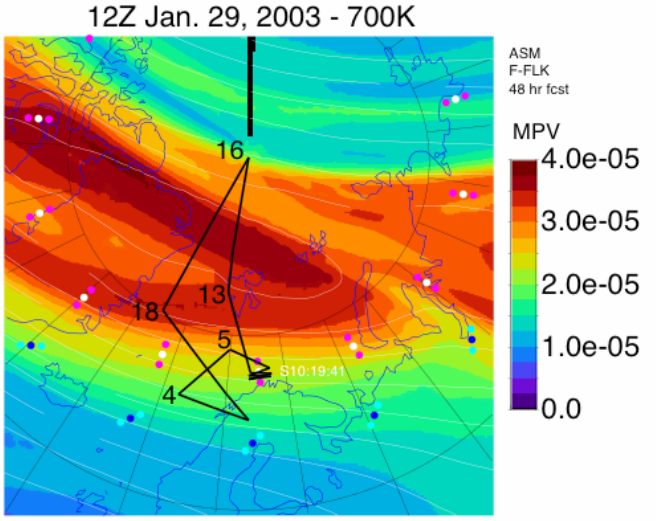

Figure 5. As in the previous figure, but for the 700-K isentropic surface (approximately at 27 km).

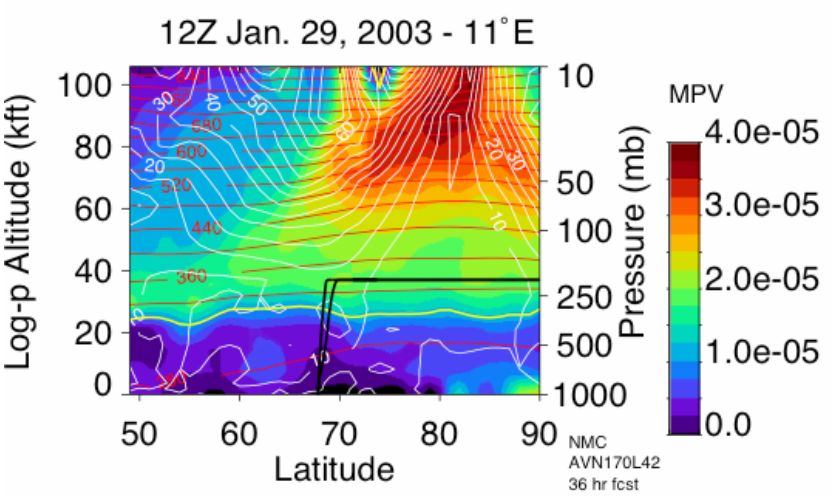

Figure 6. Transect plot from 50˚N to 90˚N at a longitude of 11˚E. The colors indicate potential vorticity values, where red-orange shows vortex material, and blues-green shows mid-latitude material. Red contours are potential temperature (K), white contours are wind speeds (m/s), and the yellow contour shows the tropopause. Ignore PV values below the tropopause.

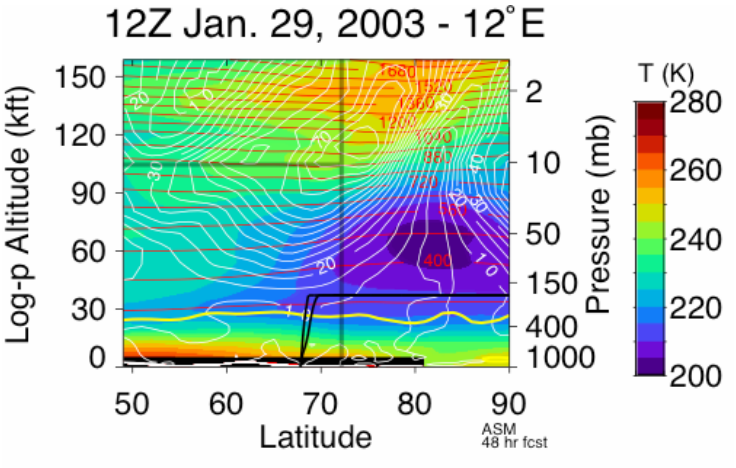

Figure 7. Transect plot from 50˚N to 90˚N at a longitude of 11˚E. The colors indicate temperature values (see scale to the right). Red contours are potential temperature (K), white contours are wind speeds (m/s), and the yellow contour shows the tropopause.

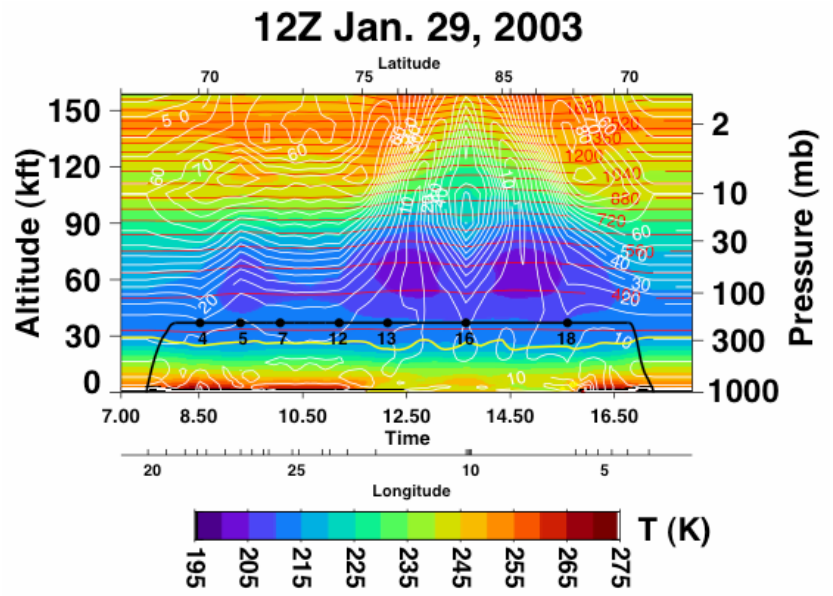

Figure 8. Curtain plot following the flight of January 29, 2003. The colors indicate temperature values (see scale at bottom of the figure). Red contours are potential temperature (K), white contours are wind speeds (m/s), and the yellow contour shows the tropopause.

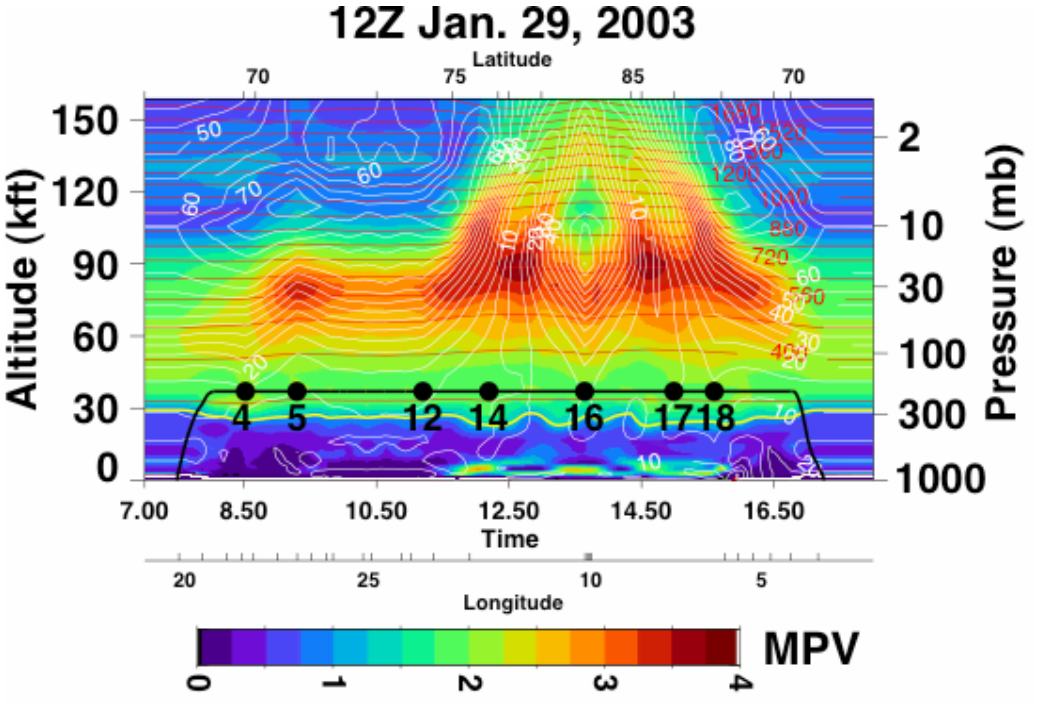

Figure 9. Curtain plot following the flight of January 29, 2003. The colors indicate p values (see scale at bottom of the figure). Red contours are potential temperature (K), white contours are wind speeds (m/s), and the yellow contour shows the tropopause.

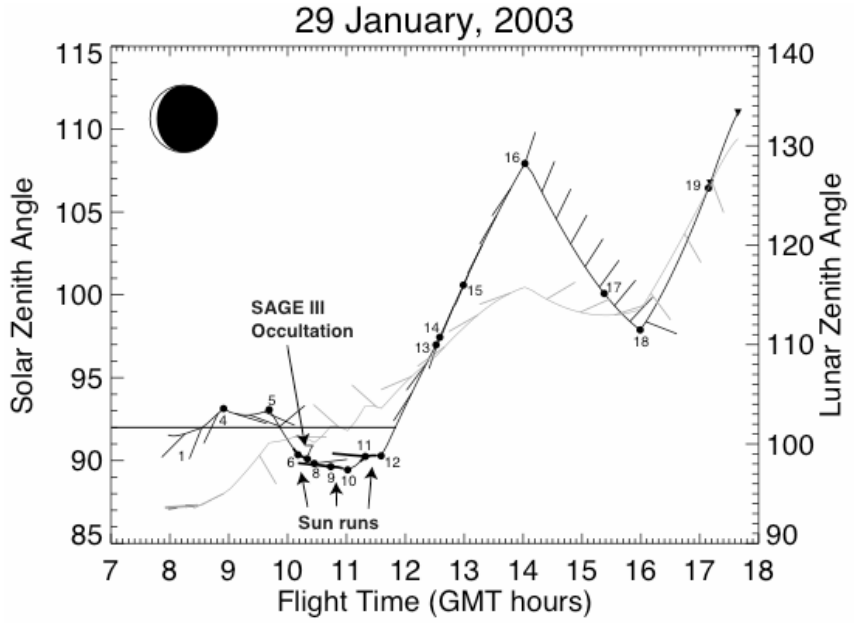

Figure 10. Solar and lunar zenith angles for the flight path shown in the previous figures.